High-frequency electron beam motion observed and resolved.

Michael C. Martin, John M. Byrd, and Wayne R. McKinney
Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

After implementing several changes to the beamline to reduce the coupling to external physical vibrations, a new much higher frequency source of noise was observed on the measured IR spectra at ALS Beamline 1.4.3. Figure 1 shows two examples of this noise where 128 FTIR scans were obtained and then another 128, with the two measurements ratioed to one another. This results in a signal to noise spectra around a 100% line (if there is no noise, the result should be a perfectly straight line). The data show that the noise is not uniform throughout the spectral region, but is instead much more pronounced in the 2 – 8 kHz region. These frequencies are much higher than the physical motion of a mirror could produce, so we had to assume that the extra noise was coming from motion of the electron beam itself.

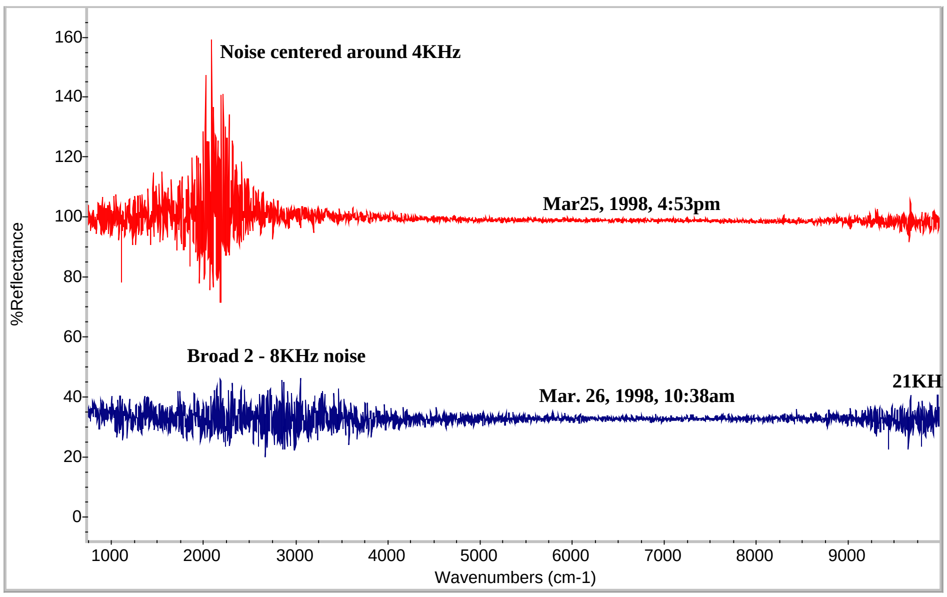

Figure 1. FTIR Spectra showing extra noise in the 2 – 8 kHz frequency regime.

The frequency dependence of this noise as a function of beam current was measured by placing a spectrum analyzer directly on the IR detector output and stopping the scanning mirror in the interferometer. The frequency spectrum was observed to change as the beam decayed, further indicating that the source is on the electron beam. During 2-bunch mode operations (when the longitudinal feedback system is not operated) we clearly observed the known synchrotron oscillations of the electron beam, and we could follow these oscillations as a function of beam energy. This proved that the FTIR setup was indeed capable of measuring electron beam motion.

After a presentation given to the Accelerator Physics Group by Michael Martin, John Byrd of that group recognized that the high frequency noise we observed is consistent with a Robinson effect beam motion if something was driving the electron bunches anywhere near these frequencies. A monitoring system in the ALS control room was set up to measure the longitudinal beam motions. Through several comparisons of the spectra versus beam current we showed that this control room measurement was indeed seeing the same beam motion that was observed with the IR beamline. Now that the beam motion was confirmed and understood to be an instability in the beam, the search turned toward identifying the driving source of the noise.

There are only a few places in which a high-frequency electric field could interact with the beam, namely the 500MHz RF cavities, the longitudinal and transverse feedback systems, and the pinger. The pinger is not used in regular operations, ruling it out. The fact that we did not observe this high-frequency noise in our earlier studies in the fall of 1997, whereas we do observe them in the winter and spring of 1998 indicates that something changed during that time. A new digitally synthesized master oscillator for the RF system was installed in December 1997 replacing an older crystal oscillator. A careful analysis of the noise output from this synthesizer was performed and showed sideband phase noise around the primary 500MHz signal. This was therefore the likely culprit.

A new HP digital synthesizer with a lower noise spec was identified and HP loaned a unit to the ALS for testing purposes during the first week of August 1998. This unit was installed in the RF system and testing was done throughout the week to monitor beam motions. The IR spectra measured with the new oscillator is compared to the previous measurements in Figure 2. The bottom spectrum represents the new measurement and clearly the 2 – 8 kHz noise is way down. Indeed most of the deviations from 100% in the 1000 – 4000 cm^{-1} region are actual changes in the water vapor and CO_2 content in the IR path and therefore are real data. The RMS noise values are seen to decrease throughout the spectral region measured. The noise in the spectroscopically critical 1000 – 4000 cm^{-1} region went from unusable, to nearly the same as in the rest of the spectrum. The high-frequency noise extended even up above 5000 cm^{-1}, where an improvement in the RMS noise of up to a factor of eight was seen. Figure 3 shows the significant reduction in noise power as seen in the control room.

The new lower-noise HP digital synthesizer has been purchased by the ALS and was installed permanently as the master oscillator in the RF system on September 14, 1998. This work has therefore lead to an improved ALS beam for every research project at the ALS.

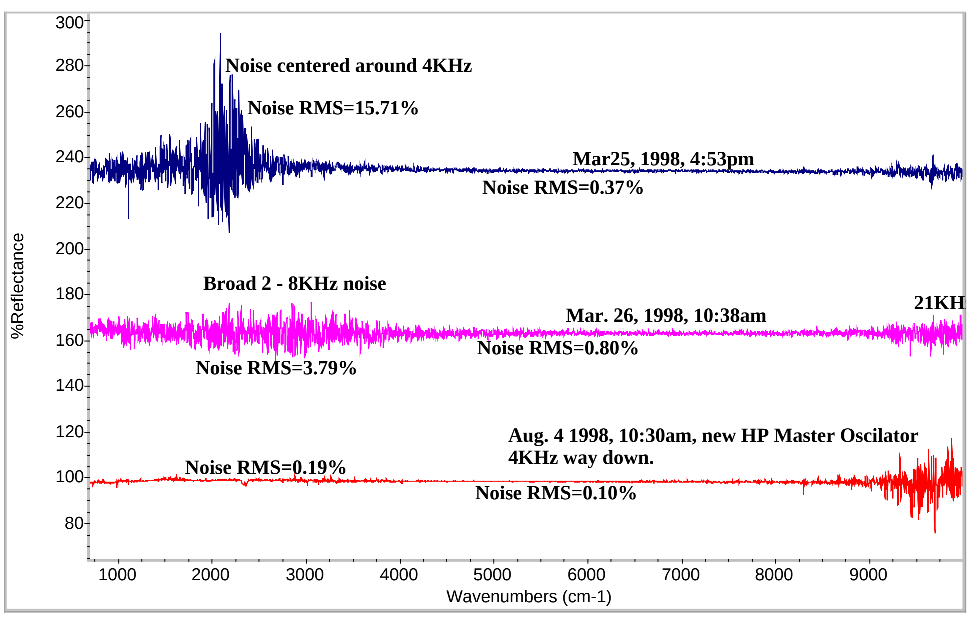

Figure 2. Comparison of the high frequency noise with the old and new digitally synthesized master oscillators.

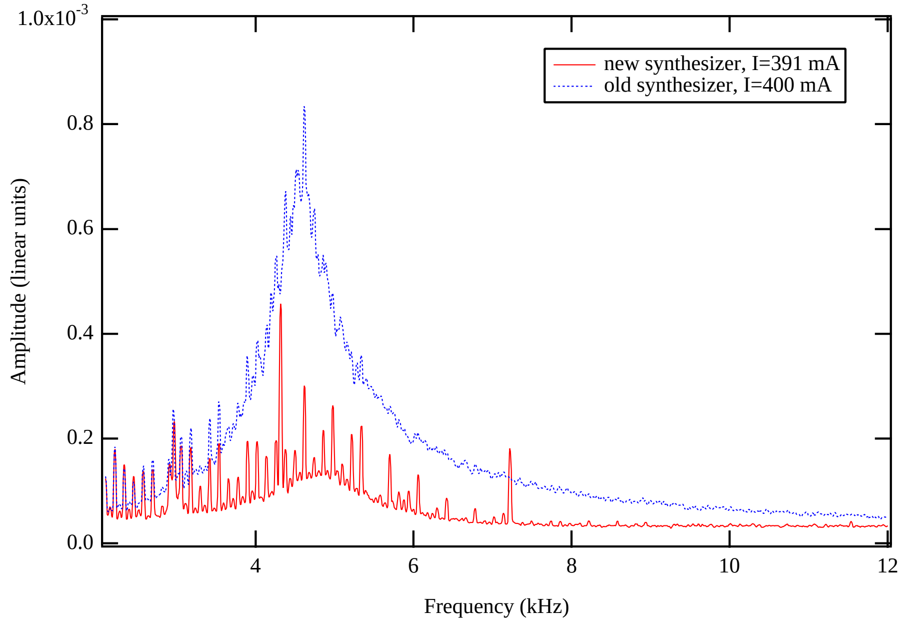

Figure 3. Measured power spectrum of synchrotron oscillations with the old and new 500 MHz master oscillators. Harmonics of the klystron power supply are now visible with the reduction in master oscillator phase noise.

The Advanced Light Source is supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Science Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098 at Lawrence Berkeley National Laboratory.

Principal investigator: Michael C. Martin, Advanced Light Source, Ernest Orlando Lawrence Berkeley National Laboratory. Email: MCMartin@lbl.gov. Telephone: 510-486-2231.